

EFFECT OF CCC, LIGHT
INTENSITY AND NITROGEN
RATE ON COTTON (Gossypium hirsutum L.)

By

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TABLE OF CONTENTS

	Page
ACKNOWLEDGMENTS	ii
LIST OF TABLES	iv
LIST OF FIGURES	vii
ABSTRACT	viii
INTRODUCTION	1
LITERATURE REVIEW	4
MATERIALS AND METHODS	13
Greenhouse Studies	13
Field Studies	15
RESULTS AND DISCUSSION	18
Greenhouse Studies	18
Field Studies	32
SUMMARY	43
Greenhouse Studies	43
Field Studies	44
LITERATURE CITED	45
APPENDIX	49
BIOGRAPHICAL SKETCH	69

LIST OF TABLES

<u>Table</u>		<u>Page</u>
1	Effect of CCC on flowering rate of cotton.	19
2	Effect of CCC on cotton boll set.	20
3	Effect of CCC on cumulative number of cotton bolls set per plant.. . . .	23
4	Effect of CCC on cotton yield.. . . .	24
5	Effect of CCC on cotton internode length and plant height.. . . .	26
6	Effect of CCC on cotton seed index and germination.. . . .	28
7	Effect of light intensity on flowering rate of cotton.. . . .	29
8	Effect of light intensity on cumulative percent cotton boll set per plant.. . . .	30
9	Effect of light intensity on cumulative number of cotton bolls set per plant.	31
10	Effect of light intensity on cotton yield.. . . .	33
11	Effect of light intensity on cotton internode length and plant height.. . . .	34
12	Effect of light intensity on number of days from open cotton bloom to open boll.. . . .	35
13	Effect of light intensity on cotton lint percent.. . . .	35
14	Effect of CCC on cotton plant height.	37
15	Effect of CCC on cotton yield.. . . .	38
16	Effect of CCC on cotton quality.. . . .	39
17	Effect of nitrogen rate on flowering and boll set of cotton.	41

<u>Table</u>	<u>Page</u>
18 Effect of nitrogen rate on cotton plant height..	41
19 Effect of nitrogen rate on cotton yield.	42

Appendix Table

1 Effect of CCC on flowering rate of cotton.	50
2 Effect of CCC on percent cotton flower set per plant.	51
3 Effect of CCC on cumulative percent cotton boll set per plant.	52
4 Effect of CCC on number of days from open cotton bloom to open boll..	53
5 Effect of CCC on cotton lint percent..	54
6 Effect of CCC on rate of cotton boll development and root system weight..	55
7 Effect of CCC on mineral content and reducing sugars in cotton leaves..	56
8 Effect of light intensity on flowering rate of cotton..	57
9 Effect of light intensity on percent cotton flower set per plant..	58
10 Effect of light intensity on cotton boll set.	59
11 Effect of light intensity on cotton seed index and germination.	60
12 Effect of CCC on flowering rate and boll set of cotton..	60
13 Effect of CCC on cotton fiber elongation..	61
14 Effect of CCC on mineral content of cotton leaves.	62

<u>Table</u>	<u>Page</u>
15 Effect of CCC on cotton yield..	63
16 Effect of CCC on cotton boll rot.	63
17 Effect of CCC on cotton defoliation.. . . .	64
18 Effect of nitrogen rate on cotton fiber elongation.	64
19 Effect of nitrogen rate on mineral content of cotton leaves.	65
20 Effect of nitrogen rate on cotton yield.. . .	65
21 Effect of nitrogen rate on cotton quality.. .	66
22 Effect of nitrogen rate on cotton boll rot. . .	67
23 Effect of nitrogen rate on cotton defoliation..	67

LIST OF FIGURES

<u>Figure</u>		<u>Page</u>
1	Effect of CCC on total % cotton boll set per plant	22
 <u>Appendix Figure</u>		
1	Total rainfall per month for 1972, showing departure from normal.	68

Abstract of Dissertation Presented to the
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Greenhouse and field studies were conducted to determine the response of cotton (Gossypium hirsutum L.) to CCC, light intensity and N rates.

Effects of CCC in greenhouse studies included: (1) increased % boll set and number of bolls set during the early flowering period but reduced boll production later in the season; (2) retarded plant height and internode length of mainstems and fruiting branches; (3) decreased leaf content of K; (4) increased leaf content of N; (5) increased seed germination and (6) heavier seed. CCC had no statistical effect at the 5% level on leaf content of reducing sugars, number of days from open bloom to open boll and rate of boll development. Although there was no statistical difference

between root system weights, visual observation indicated that CCC may have increased the number of fibrous roots.

Effects of CCC in field studies included: (1) retarded plant height; (2) increased Ca and Mn content of leaves; (3) greater fiber strength; (4) reduced lint percentage and (5) lower yield. CCC had no effect on cotton yield at rates of 35 g (a.i.) per ha or less. CCC had no effect on flowering rate, number of bolls set for the 3 weeks immediately following chemical application, fiber elongation, boll size, fiber length, fineness and uniformity.

Plants subjected to low light intensity in greenhouse studies: (1) fruited slower and with less efficiency than plants grown under normal light; (2) produced taller plants with longer mainstem and fruiting branch internodes; (3) required more days to develop an open boll from an open bloom. There were no treatment effects on lint %, seed index and germination percentage of seed from plants grown under the 3 levels of light intensity.

In field studies, N at 168 kg per ha increased flowering rate over the rate of 84 kg, but % flower set was greater under low N. Cotton yields were not different. High N increased leaf N content and plant height. Also, the plants were slightly more difficult to defoliate. Fiber quality characteristics, boll size and rate of fiber elongation were not affected by N treatment.

Dry weather may have been responsible for no interaction between CCC and N rates in this study.

INTRODUCTION

Man have been producing, spinning, and weaving cotton fiber since the dawn of civilization, and it has been a part of the history of every continent.

Eli Whitney's gin and the industrial revolution helped establish the United States as a commercial power and spurred the growth of a new nation. Demands of mills in New England and a growing textile industry in this country caused growers of the Southeast to push southward and westward in search of new lands. They moved into Alabama and Tennessee, onward into Texas and even farther west. Today, the 18-state Cotton Belt stretches from the Carolinas to California and leads the world in cotton production, accounting for about 20% of the total supply.

Cotton exports in 1970 were valued at nearly \$492 million as contrasted with exports of less than \$195 million for man-made fibers. Imports of synthetics exceeded exports by \$11 million -- a deficit in trade value. Net earnings of badly needed foreign exchange amounted to \$362 million for cotton.

Cotton is the leading raw material of the textile and apparel industries which in 1968 employed 2.3 million people

with a payroll of \$10.9 billion dollars -- second only to metals among manufacturing industries.

The American revenue from cotton and cottonseed at the farm level averages about \$2.2 billion annually. This represents new wealth, replenishing the economy each year to be multiplied many times over in the journey to consumer.

Some 300,000 cotton farms in the United States provide full employment for an estimated 500,000 operators and workers. Another 47,000 workers are employed during the peak seasons. Some 40,000 are engaged in ginning, 10,000 in warehousing and about 5,700 in cottonseed oil mills.

Numerous changes have taken place in cotton production during the last decade. Increased mechanization, especially mechanical harvesting, has resulted in certain cultural changes. For example, higher plant populations increased internode length and height of the first boll from the ground. This is desirable for machine harvesting. Higher plant populations also increased plant height.

Almost all cultural changes during the last decade have resulted in increased vegetative growth. These include better land preparation, greater fertilizer and lime use, improved rotations, better pest control and more vigorous varieties.

Cultural changes have been desirable since more extensive root systems reduce dry weather hazards and greater vegetative growth usually increases yield potential. However, excessive vegetative growth may result in the following:

(1) increased insect problems; (2) delayed maturity; (3) boll rot; (4) lodging; (5) reduced yield; (6) poor defoliation; (7) lower grades; (8) low harvesting efficiency.

In recent years, growth regulators have become increasingly important in agriculture. Growth regulators are being marketed for several crops, but none have been developed for cotton.

Cotton may shed 50% of its flowers, even if protected from insects, when grown over the long growing season common in the southeastern United States.

Growth regulators offer a potential for limiting leaf expansion and increasing carbohydrate reserves, thereby improving flower retention and, consequently, increasing yields. Other potential benefits of growth regulators include more uniform maturity and a reduction in the adverse effects of excessive vegetative growth.

One of the growth regulators showing promise for use on cotton is Cycocel (2-chloroethyl trimethylammonium chloride), also known as CCC.

This investigation was designed to document the effects of CCC on individual components of the cotton plant during various developmental stages. Two factors intimately associated with vegetative growth and reproduction -- N fertilization and light intensity -- also were examined to determine possible interactions with CCC.

LITERATURE REVIEW

The plant growth regulating properties of 2-chloroethyl trimethylammonium chloride (CCC) and related chemicals were reported first in 1960 by Tolbert (43). Cycocel is the trade name of American Cyanamid Company for its 1 pound per gallon formulation of CCC. For convenience, the term "CCC" is used throughout this paper when reference is made to the above chemical.

The structural formula for CCC is $\text{Cl-CH}_2\text{-CH}_2\text{-N}^+(\text{CH}_3)_3\text{Cl}^-$ with a molecular weight of 158.1. Chlormequat has been established as the generic name by the British Standards Institute.

Mode of Action

In his earliest investigations, Tolbert (44) observed that CCC and gibberellic acid produced opposite growth effects in plants. CCC has been termed, consequently, as an "antigibberellin", a term that in the biochemical sense implies specific competition between gibberellins and the growth retardant for 1 or several reaction sites in the plant. According to this definition, an antigibberellin should be a chemical analogue of gibberellic acid that can act as a substitute for the material in biochemical reactions. However, according to Tolbert (44), no evidence exists that CCC is structurally related to gibberellic acid.

Kuraishi and Muir (19) conducted experiments with CCC and indoleacetic acid (IAA) on Alaska pea plants (Pisum sativum L.). Their findings suggest that retardation of stem growth by CCC was due to a lack of IAA and was independent of gibberellins. These investigators concluded that the growth retardant interacted directly with IAA to cause a decrease in the level of diffusible auxin.

Stoddart (36) suggested that CCC obstructs the metabolic system of plants because it interrupted nutrient assimilation and growth of Lolium temulentum L. He observed that stem elongation was arrested by CCC while photosynthesis proceeded at an appreciable rate. Thus, he concluded that free sugars normally utilized to sustain growth were polymerized, in the presence of the compound, to form storage carbohydrates.

Bristow (8), working with meristematic sections of Pteris cretica L. leaves, found that CCC strongly inhibited growth of leaf sections but the effect was completely reversed by gibberellic acid.

Despite extensive experimental evidence that points to suppression of gibberellin biosynthesis as the probable mode of action, results of Khan and Tolbert (17) suggest that CCC may act through other routes as well. When either IAA or coumarin was applied to lettuce seeds (Lactuca sativa L.) in light, germination and root growth were inhibited. Application of CCC in light reversed these effects, while application of gibberellin did not. Sachs and Wohlers (34)

have also reported that CCC effects are not restricted to suppression of gibberellin biosynthesis. CCC inhibited cell division and enlargement of tobacco, chrysanthemum, and carrot tissue cultures in vitro. However, gibberellic acid did not prevent the retardant-induced inhibition in vitro as it does with intact plants. Likewise, supplementary auxin did not reverse the inhibitions. Thus, the investigators concluded that the effect of CCC cannot be simply that of suppressing gibberellin or auxin synthesis.

Azaleas

McDowell and Larson (26) subjected azalea cultivars (Rhododendron obtusum L.) to short day length (8 hours) and natural day length (14 hours, 41 minutes) and found that CCC treatments applied to the Redwing variety caused earlier flower bud initiation and a greater rate of floral development. Cathy and Stuart (9) noted that foliage of treated azalea plants was much darker green than that of control plants. Stuart (37) and Gill (11) observed an increase in the number of flowers, although Gill reported blooming time may have been delayed.

Cotton

Thomas (40) treated Gossypium hirsutum L. plants with foliar sprays of 25 to 100 ppm CCC. Applications were made at flowering and 2 weeks before and after flowering. Within 10 days of treatment, significantly shorter stems and greener foliage were observed. Fruiting branch

elongation was suppressed so that bolls on adjacent nodes almost touched. Rate of flowering was inhibited and seedcotton production reduced.

Thomas (41) found that 18 to 140 g (a.i.) per ha CCC applied at peak of flowering, reduced plant height. Yields were only slightly decreased and he suggested that chemical retardants could potentially minimize undesirable late season growth and fruiting of cotton.

Hamawi (14) applied single and repeated foliar sprays of CCC to Gossypium barbadense L. at rates of 5, 10, 25, 50 and 75 ppm. Earlier and more uniform flowering were observed in treated plants. Yields were increased at dosages of 25 and 50 ppm, decreased at 75 ppm and not affected at 5 ppm.

Gutierrez (12) found that cotton yields were increased when treated 70 days after emergence at the rate of 10 g (a.i.) per ha. CCC increased boll frequency, but had no effect on the number of fruiting branches. Thus, the main treatment effect appears to be increased boll retention which gives higher yield. No effect was noted on plant height.

Singh (35) in 1970 established 93 demonstration plots in which 1 acre plots were divided into 4 equal blocks. Two blocks were sprayed with water and the other 2 with 32 ml of 50% CCC per acre, 75-90 days from planting. Average yield increase of all treated plots was 15%. Singh

concluded that yield increases were due to increased root systems in relation to shoot growth, resulting in greener leaves because of higher nutrient and water content; as a consequence, plants remained physiologically active longer and produced heavier bolls.

Gausman et al. (10) reported that leaves of cotton sprayed with CCC at the rate of 100 g (a.i.) per ha were 40% thicker and had 20% greater surface area. CCC-treated leaves had a 3-fold increase in number of intercellular spaces within mesophylls. Spectrophotometric measurements of spectra of individual leaves over the wavelength interval 500-2500 nm revealed a 5% increase in reflectance and a 6% decrease in transmittance for treated compared to untreated leaves.

Bhatt and Seshadrinathan (4) found that CCC enlarged the spongy parenchyma more than the palisade in G. hirsutum L. varieties but reversely affected G. barbadense L. varieties. CCC also increased thickness of the upper epidermis. The research workers suggested that CCC may induce tolerance to drought by developing wider and stronger palisade and thicker leaves.

Poinsettia

Lindstrom and Tolbert (21) in 1960 observed that CCC altered growth characteristics of poinsettia (Euphorbia pulcherrima W.) but did not change the number of leaves or number of days to flowering. CCC treated plants were shorter

with darker green and thicker leaves. Later, Besemer (3) found that poinsettia bract diameters were reduced by CCC.

Larson and McIntyre (20) reported that cuttings from CCC treated stock plants resulted in excellent quality plants. Stock plants were treated with either a foliar spray or a soil drench at 2,950 ppm and no further application was made to cuttings.

Tomatoes

In 1960, Wittner and Tolbert (45) described tomatoes (Lycopersicon esculentum M.) treated with foliar application of CCC as having shorter internodes, darker green foliage and more leaf chlorophyll. Tiessen (42) reported the same changes in plant characteristics when the product was applied as a soil drench.

Abdalla and Verker (1) investigated the effect of CCC on tomatoes at 2 temperature regimes: 35° C day and 25° C night compared to 22° C day and 18° C night. CCC retarded stem growth at both temperatures but plants at high temperature resumed normal growth rate sooner. Applied to soil at start of flowering, CCC reduced flower shed and increased fruit set and development at the high temperatures. However, at the lower temperature levels, there were no clear effects of CCC. The researchers also found that plants treated with CCC accumulated a higher tissue N level.

Cereal Grains

Many investigators including Linser et al. (23), Mayr et al. (25), Primost (31), and Tolbert (43) have reported that the enhanced stem strength and dwarfed growth induced by CCC in wheat plants (Triticum vulgare V.) prevented or suppressed lodging.

Greater tolerance to such stress conditions as drought and soil salinity has been reported by Miyamoto (27). Adler (2) showed that CCC increased both total root growth and number of wheat kernels per head.

Bokhari and Youngner (6) found that barley (Hordeum vulgare L.) responded more to CCC soil drench than to foliar sprays and attributed the yield increase to more head-producing tillers and heavier kernels. These same investigators (7) later determined by microscopic examinations that tiller primordia were present in most leaf primordia axils of young untreated plants. They concluded that growth of these primordia was promoted by CCC.

Johnson and Schafer (16) observed that CCC caused wheat plants to remain sturdy and non-etiolated in thick plantings for a longer time than untreated plants.

Ota, et al. (29) reported that CCC retarded stem elongation in rice. Later, these same investigators (30) observed that rice (Oryza sativa L.) responded to treatment only when sown thickly. Tolbert (44) found that CCC-treated

oats developed shorter internodes. Linser and Kuhn (22) noted a similar effect on rye (Secale cereale L.), which was also resistant to lodging.

Kuhn (18) observed improved seedling vigor and plant development in plants grown from treated seed. He concluded that optimum rates of foliar sprays on cereal grains varied according to environmental conditions and plant variety.

Miscellaneous Responses

Halevy and Kessler (13) showed that CCC increased tolerance to stress conditions such as drought, frost and soil alkalinity of various plants treated with CCC. Greater frost resistance in cabbage (Brassica oleracea L.) was also recorded by Marth (24).

Read and Hoysler (33) dipped herbaceous cuttings in a CCC solution and observed a marked suppression of adventitious root production.

Hore and Bose (15) treated numerous species of flowering shrubs and observed increased flowering, with more than a 100% increase in Clerodendron macrosphum L. Increased flower and fruit production of lemons was reported by Monselise and co-workers (28).

Ray and Schroder (32) found that sunflower (Helianthus tuberosus L.) plants grown from seed soaked in a CCC solution were shorter than control plants. However, the researchers concluded that soil applications were much more effective than seed treatments, perhaps because much larger quantities of the chemical were absorbed by the roots.

Bobak (5) working with Vicia faba L., noted that certain concentrations of CCC caused such phenomena as stickiness and disturbance of chromosome matrix besides a decrease of cell division. Tanaka (39) and co-workers concluded that CCC stimulated activity of partially purified choline kinase, had no effect upon activity of plant phosphorylcholine nor upon ATPase from wheat roots or leaves.

Tahori et al. (38) tested CCC for effects of feeding by cotton leafworms on beans. After 13 days, 72% of the control plants were destroyed compared to only 13% of the plants sprayed with CCC.

MATERIALS AND METHODS

I. Greenhouse Studies

The studies were conducted at the Coastal Plain Experiment Station, Tifton, Georgia. One of the experiments was designed to document effects of various rates of CCC on cotton growth and development under 3 levels of light intensity. A 3x8 factorial with 6 replications was arranged in a completely randomized design.

The greenhouse was divided into 3 equal sections with light intensities serving as whole plots and established as follows:

A. High Light Intensity - To increase light reflection throughout the cotton canopy, pots were wrapped with aluminum foil and placed on the greenhouse floor, which was covered with the same material. Aluminum foil partitions surrounded the high light intensity plot. Six fluorescent daylight bulbs (2.4 m long) were suspended above the plants and controlled with a time clock to come on at 6 a.m. and go off at 8 p.m. Light meter measurements at various times during the experiment indicated the light intensity here to be 120% of normal.

B. Low Light Intensity - Light intensity was reduced to approximately 50% of normal by suspending wooden frames covered with polypropylene shade cloth above the plants.

C. Normal Light Intensity - The normal light treatment was sunlight filtered by greenhouse covered by a thin coat of latex paint.

CCC rates served as sub-plots and were as follows:
0, 9, 18, 35, 70, 140, 280 and 560 g (a.i.) per ha.

A Tifton sandy loam soil with pH 5.8 was mixed with peat moss in a ratio of 3 to 1 by volume. The soil mixture contained 1121 kg per ha each of lime and 5-10-15 fertilizer. In order to assure adequate blending, the soil, peat, lime and fertilizer were mixed together in a concrete mixer.

Four seed (cv. Coker 310) per pot were planted in 4-gallon plastic containers on April 4, 1972. Later each pot was thinned to 1 plant. CCC was applied in 94 liters of diluted solution per ha on May 31, 1972, 57 days after planting, when plants were about 76 cm tall (approximately first flower).

Flowers were tagged and counted daily for 7 weeks for calculation of weekly flowering rate, cumulative flowers at selected dates and boll set. Number of days from open flower to open boll was determined.

Plant height was measured 30 days after CCC treatment and at maturity. Average internode length for both mainstem and fruiting branches was recorded 30 days after treatment. Mainstem internode length was determined by averaging the second through the fifth internodes below the terminal bud. Fruiting branch internodes were measured by averaging 3

internodes on the second, third and fourth fruiting branch from the terminal bud.

Yield was recorded as number of bolls and g of seedcotton per plant. The seedcotton was ginned on a small portable roller gin and seed index calculated as g per 100 seed. The effect on germination was tested by placing 100 seed, divided into 2 replicates, in a seed germination chamber for 7 days. Temperatures automatically rotated to 20° C for 16 hours and 30° C for 8 hours.

In order to further evaluate the effects of CCC on cotton, another experiment was initiated in a similar manner to that previously described except light intensity variables were omitted. The test was arranged in a completely randomized design and replicated 6 times.

Rate of boll development was determined by oven-drying and weighing bolls removed 10, 20 and 30 days after flowering. Young mature leaves were selected 44 days after CCC treatment. These were air-dried and ground in a Wiley mill. Plant samples were analyzed for reducing sugars and mineral element content. Root weights were recorded after washing, screening, and oven-drying.

II. Field Studies

A field study was designed to observe the effects of CCC on cotton grown at different levels of N fertilization. A 2x6 factorial experiment was arranged in a randomized

complete block design with 4 replications. Nitrogen rates were 84 and 168 kg per ha. CCC was applied at 0, 9, 9 (3 times, 10 days apart), 18, 35 and 280 g (a.i.) per ha.

The Coker 310 cv. was planted May 10, 1972, on a Tifton sandy loam soil (pH 5.8) at the Coastal Plain Experiment Station, Tifton, Georgia. Each plot contained 4 rows (96.5 cm apart and 14 m long). Observations were made on the 2 center rows. The entire area received 448 kg per ha of 7-14-21 fertilizer prior to planting and 560 g per ha of B on the foliage at early squaring. Nitrogen was applied by hand on June 6, 1972. Weed control consisted of 560 g trifluralin incorporated before planting, 168 g fluometuron preemergence at planting and 3 mechanical cultivations.

CCC was applied with a high clearance sprayer as a foliar spray in a 188 liters per ha diluted solution on July 11, 1972, (62 days after planting) at approximately 1 week after first bloom.

Flowers were tagged and counted daily except Saturdays and Sundays on a 3.05-m row segment for 3 weeks immediately following CCC application. Flowering rate, % boll set and cumulative boll set were observed in this 3-week period.

Average plant height was calculated at 15 and 30 days after CCC treatment and also at maturity. Plant analysis of youngest mature leaves for mineral element content was made at 30 days from treatment on August 10, 1972.

Flowers were tagged on July 21, 1972, (10 days after CCC treatment). Bolls were removed at 5, 10, 15, and

20 days after tagging and fiber length measured. To determine fiber length, a lock from a boll was placed in a beaker of boiling water (for bolls 20 days old, 2.5% HCl was used) to dissolve simple sugars and allow the seed with attached fiber to float free. The seed were then floated out on the convex side of a watch glass, the fiber made to stream out with a jet of water and length measured with a centimeter rule. All measurements were made from the rounded chalaza end of the immature seed. Fiber of 8 to 10 seed per boll from 3 different bolls was measured and averaged for each determination.

Other measurements included the effect of CCC and N rates on boll rot, % defoliation and yield. Also, samples of 50 bolls per plot were hand picked, ginned and used to determine boll size, lint %, fiber length, strength and micronaire.

RESULTS AND DISCUSSION

Effects of CCC were visible in all studies within 2 weeks after treatment. CCC treated plants had less height and internode length. Leaves were thicker and greener on treated plants. Bolls were spaced so close they almost touched each other where highest rates of CCC were used.

Greenhouse Studies

CCC

Flowering rate and boll set were recorded daily for 7 weeks after CCC application. Flowering rate reached a peak during the fourth week of flowering (Appendix Table 1). CCC did not significantly affect flowering rate until after completion of the first 4 weeks of flowering (Table 1). Cumulative flowering rate was reduced after the fifth week by CCC rates of 35 g (a.i.) per ha and greater. The reduction in flowering rate was due to an apparent lack of new fruiting bud development. CCC was so effective that no new vegetative and/or fruiting branches formed; consequently, fruiting ceased.

CCC treatment caused no significant differences in percentage of cotton flowers set during the initial 4 weeks of flowering (Appendix Table 2). However, 140 g (a.i.) per ha, or more, of CCC reduced percentage of flowers set during the fifth and sixth weeks. There were no differences

Table 1. Effect of CCC on flowering rate of cotton.¹

CCC rate g (a.i.)/ha	Weeks from first flower						
	1	1-2	1-3	1-4	1-5	1-6	1-7
	cumulative flowers/plant						
0	0.6	3.8	9.3	15.8	22.4a	27.8a	29.3a
9	0.6	3.9	9.0	15.2	21.1ab	25.9abc	27.2abc
18	0.5	3.7	9.4	15.9	21.6ab	26.9ab	28.8ab
35	0.8	3.9	9.1	14.6	20.7abc	24.1 bc	25.3 bc
70	0.6	4.0	9.2	14.8	20.0 bc	23.7 bc	24.7 c
140	0.7	4.2	9.6	14.7	19.9 bc	23.8 bc	24.9 c
280	0.8	4.3	9.4	15.6	20.4abc	24.2 bc	24.7 c
560	0.7	4.4	9.7	14.2	18.8 c	22.7 c	24.0 c

¹ Treatments not followed by the same letter differ significantly at the 5% level according to Duncan's Multiple Range Test. There are no significant differences between treatments in columns that have no letters.

Table 2. Effect of CCC on cotton boll set.¹

CCC rate g (a.i.)/ha	Weeks from first flower						
	1	2	3	4	5	6	7
	bolls/plant/week						
0	0.61	2.78	2.17	2.06a	2.39a	1.50a	0.28
9	0.56	3.11	1.94	1.72a	2.33a	1.72a	0.11
18	0.39	2.94	2.39	1.78a	2.00ab	1.28ab	0.11
35	0.78	2.89	2.17	1.67a	1.61ab	1.17ab	0.0
70	0.56	3.11	2.61	1.72a	1.44 b	1.17ab	0.0
140	0.67	3.39	2.72	1.28ab	0.56 c	0.89abc	0.50
280	0.78	3.33	2.94	1.56ab	0.67 c	0.39 bc	0.11
560	0.72	3.67	2.72	0.83 b	0.56 c	0.17 c	0.0

¹ Treatments not followed by the same letter differ significantly at the 5% level according to Duncan's Multiple Range Test. There are no significant differences between treatments in columns that have no letters.

in cumulative percentage flower set for weeks 1-4 or weeks 1-7 (Appendix Table 3). Even so, there appears to be a trend with CCC increasing flower set during the first month of flowering (Figure 1).

Boll set was reduced by the 560 g (a.i.) per ha of CCC during the fourth week of flowering (Table 2). Rates of 70 g (a.i.) and greater increased boll set the fifth week, as did rates 280 g (a.i.) and greater the sixth week of flowering. The reduction in number of bolls set in late season from the higher rates of CCC is due both to a reduction in flowering and % flower set. Actually, CCC treatment increased the number of bolls set per plant during the first 3 weeks of flowering (Table 3). However, total boll set per plant for the entire growing season was reduced when CCC rates were 140 g (a.i.) or greater per ha. The 560 g rate reduced boll set by about 26%.

Total boll set per plant can be used as a indicator of yield (Table 4). However, fruiting period under field conditions is quite variable due to influence of genetic, environmental and insect factors. For example, an early freeze or dry conditions in September can completely stop fruiting. Therefore, careful evaluation of cumulative boll set at various intervals is encouraged rather than total boll set for the entire season.

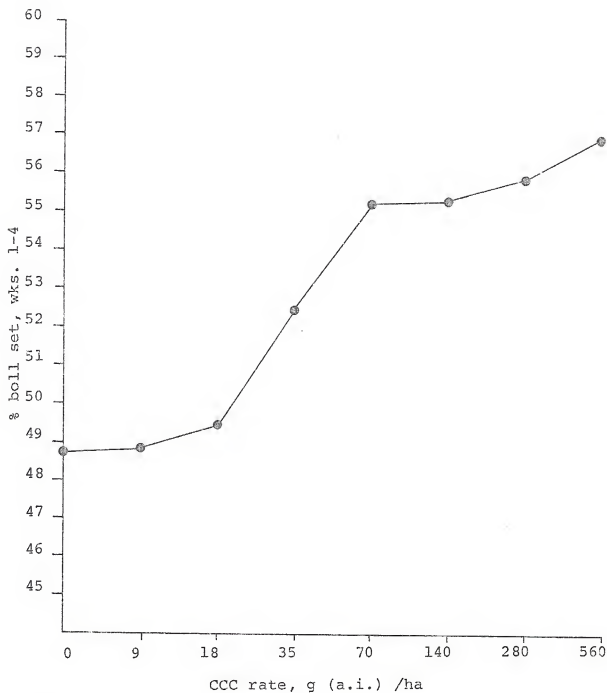


Figure 1. Effect of CCC on total % cotton boll set per plant during first 4 weeks of flowering.

Table 3. Effect of CCC on cumulative number of cotton bolls set per plant.¹

CCC rate g (a.i.)/ha	Weeks from first flower						
	1	1-2	1-3	1-4	1-5	1-6	1-7
	cumulative bolls set/plant						
0	0.6	3.4	5.6 c	7.6	10.0	11.5a	11.8a
9	0.6	3.7	5.6 c	7.3	9.7	11.4a	11.5ab
18	0.4	3.3	5.2 c	7.5	9.5	10.8ab	10.9abc
35	0.8	3.7	5.8 bc	7.5	9.1	10.3ab	10.3abc
70	0.6	3.7	6.3abc	8.0	9.4	10.6ab	10.6abc
140	0.7	4.1	6.8ab	8.1	8.6	9.5 bc	9.7 cd
280	0.8	4.1	7.1a	8.6	9.3	9.7 bc	9.8 cd
560	0.7	4.4	7.1a	7.9	8.5	8.7 c	8.7 d

¹ Treatments not followed by the same letter differ significantly at the 5% level according to Duncan's Multiple Range Test. There are no significant differences between treatments in columns that have no letters.

Table 4. Effect of CCC on cotton yield.¹

CCC rate g (a.i.)/ha	Bolls/plant no.	Seedcotton/plant g
0	11.8a	48.5
9	11.5ab	54.6
18	10.9abc	50.0
35	10.3 bc	49.2
70	10.6abc	54.4
140	9.7 cd	49.1
280	9.8 cd	53.6
560	8.7 d	49.1

¹ Treatments not followed by the same letter differ significantly at the 5% level according to Duncan's Multiple Range Test. There are no significant differences between treatments in column that has no letters.

There were no statistical differences between weights of seedcotton due to treatments (Table 4). Weights were influenced by severe boll rot which occurred during boll opening. The rot was probably due to high humidity in the greenhouse.

Plant height and internode length were affected by CCC (Table 5). Plants sprayed with rates of 18 g (a.i.) or higher per ha had shorter mainstem and fruiting branch internodes. Plant height 30 days after treatment and at maturity was significantly less in all plants treated with CCC. Heights ranged from 9 to 33% less than checks, depending on chemical rate.

CCC had no effect on time from open bloom to open boll, cotton lint %, or rate of boll development (Appendix Tables 4, 5, and 6). Visual observations of washed roots suggested that CCC treatment may have increased number of fibrous roots, although root weights did not bear out this observation (Appendix Table 6).

CCC treatment affected mineral content but had no effect on reducing sugars (Appendix Table 7). Amount of reducing sugars is one indicator of photosynthetic activity and/or respiration. Potassium content of leaves decreased when CCC was applied at 280 g (a.i.) or greater per ha. CCC at 560 g increased the percentage of N in the leaves. There were no differences in leaf content of other mineral elements.

Table 5. Effect of CCC on cotton internode length and plant height.¹

CCC rate g (a.i.)/ha	30 days after treatment			
	Average internode length		Plant height	Final plant height
	Mainstem cm	Fruiting branch cm		
0	6.1abc	7.3a	113.5a	149.3a
9	6.2ab	6.3abc	103.6 bc	136.8 b
18	6.5 bcd	6.5ab	107.7 b	140.4 b
35	5.5 bcd	5.4 bc	98.9 c	132.5 bc
70	5.4 cd	5.4 bc	93.2 d	126.3 cd
140	5.2 d	4.9 cd	87.1 e	118.8 de
290	4.8 d	5.2 c	87.9 de	111.7 ef
560	4.9 d	4.0 d	85.6 e	104.3 f

¹ Treatments not followed by the same letter differ significantly at the 5% level according to Duncan's Multiple Range Test.

Data in Table 6 show that seed quality was improved by CCC. Seed index was greater at all levels except the 18 g rate of CCC. Germination of seed from plants treated with CCC increased when treatment rates were 280 g and greater.

Light Intensity

Light intensity did not influence the effects of CCC measured in these studies. However, plants responded to different light treatments independently.

Low light intensity reduced flowering over the entire 7-week fruiting period (Table 7). Plants grown under normal light had a higher flowering rate the first 4 weeks. After the fourth week, there was no difference in cumulative number of flowers between high and normal light intensity. However, both high and normal light resulted in about 20% more total flowers than plants receiving low light. In addition to this lower flowering rate, the cumulative percentage of flowers set during weeks 1-4 was lower (Table 8). There were no significant differences in flower set at different light intensities over the 7-week flowering period. Plants under normal light set the largest number of bolls during weeks 1-4, followed by high light intensity plants and those receiving low light intensity set the lowest number (Table 9). Total boll set at the end of 7 weeks was significantly lower in low light intensity plots with no difference between boll set in high and normal light.

Table 6. Effect of CCC on cotton seed index and germination.¹

CCC rate g (a.i.)/ha	Seed index g/100 seed	Germination %
0	11.0 c	85.0 cd
9	11.9ab	85.5 bcd
18	11.4 bc	83.6 d
35	11.9ab	85.6 bcd
70	12.2a	86.2 bcd
140	12.2a	88.6abc
280	12.5a	90.7a
560	12.6a	89.7ab

¹ Treatments not followed by the same letter differ significantly at the 5% level according to Duncan's Multiple Range Test.

Table 7. Effect of light intensity on flowering rate of cotton.¹

Light intensity	1	1-2	Weeks from first flower				
			1-3	1-4	1-5	1-6	1-7
			cumulative flowers/plant				
High	0.6	3.8 b	9.2 b	14.8 b	21.3a	26.6a	28.5a
Low	0.6	3.7 b	8.9 b	14.4 b	18.9 b	21.9 b	22.8 b
Normal	0.7	4.5a	10.0a	16.0a	21.7a	26.2a	27.0a

¹ Treatments not followed by the same letter differ significantly at the 5% level according to Duncan's Multiple Range Test. There are no significant differences between treatments in column without letters.

Table 8. Effect of light intensity on cumulative percent cotton boll set per plant.¹

Light intensity	Weeks from first flower	
	1-4	1-7
High	53.7a	39.2
Low	48.7 b	41.5
Normal	55.9a	42.5

¹ Treatments not followed by the same letter differ significantly at the 5% level according to Duncan's Multiple Range Test. There are no significant differences between treatments in column without letters.

Table 9. Effect of light intensity on cumulative number of cotton bolls set per plant.¹

Light intensity	1	Weeks from first flower					
		1-2	1-3	1-4	1-5	1-6	1-7
High	0.6	3.6 b	6.3 b	7.7 b	9.1 b	10.6a	10.8a
Low	0.6	3.5 b	5.0 c	6.9 c	8.5 b	9.3 b	9.3 b
Normal	0.7	4.3a	7.3a	8.8a	10.3a	11.0a	11.1a

¹ Treatments not followed by the same letter differ significantly at the 5% level according to Duncan's Multiple Range Test. There are no significant differences between treatments in column without letters.

Normal light intensity resulted in the highest yield of seedcotton per plant, high light intensity being intermediate (Table 10).

Light effects on plant height and internode length appear in Table 11. Low light intensity increased mainstem internode length by 22% and fruiting branch internodes were about 33% longer than those grown under normal light intensity. Low light caused taller plants than high or normal light.

Table 12 shows that reduced light increased the number of days from open bloom to open boll. While the difference was only 2 days, it was highly significant.

Light appeared to have little effect on lint-seed measurements. Low light intensity resulted in plants with lower cotton lint percentage (Table 13), but there was no difference between normal and high light.

There was no difference in seed index or germination percentage of seed from plants grown under the 3 levels of light intensity (Appendix Table 11).

Field Studies

Excessive vegetative growth often occurs in Georgia when cotton is fertilized with high N rates. However, this was not the case in 1972, because of low rainfall (Appendix Figure 1). Moisture was deficient most of the growing season and especially during the fruiting period. For this reason, data from greenhouse studies probably describe more accurately the responses of cotton to CCC.

Table 10. Effect of light intensity on cotton yield.¹

Light intensity	Bolls no./plant	Seedcotton g/plant
High	10.8a	50.3 b
Low	9.3 b	43.9 c
Normal	11.1a	59.0a

¹ Treatments not followed by the same letter differ significantly at the 5% level according to Duncan's Multiple Range Test.

Table 11. Effect of light intensity on cotton internode length and plant height.¹

Light intensity	30 days after treatment				Final plant height cm
	Average internode length		Plant height		
	Mainstem cm	Fruiting branch cm	cm		
High	5.3 b	6.2a	97.3 b	129.2a	
Low	6.4a	6.4a	102.3a	133.3a	
Normal	5.0 b	4.3 b	92.0 c	120.1 b	

¹ Treatments not followed by the same letter differ significantly at the 5% level according to Duncan's Multiple Range Test.

Table 12. Effect of light intensity on number of days from open cotton bloom to open boll.¹

Light intensity	Open bloom to open boll days
High	52.2 b
Low	54.1a
Normal	51.9 b

¹ Treatments not followed by the same letter differ significantly at the 5% level according to Duncan's Multiple Range Test.

Table 13. Effect of light intensity on cotton lint percent.¹

Light intensity	Lint %
High	40.1a
Low	38.5 b
Normal	40.4a

¹ Treatments not followed by the same letter differ significantly at the 5% level according to Duncan's Multiple Range Test.

CCC

CCC had only a limited influence on plant height (Table 14). Only the highest rate resulted in less height; however, the lower height persisted throughout the growing season. This contrasted to a height retardation threshold of 18 g per ha in greenhouse tests. Perhaps this was a function of moisture.

CCC had no effect on flowering rate, flower set or boll set for the 3-week period immediately following chemical application (Appendix Table 12).

CCC treatment did not influence the rate of fiber elongation as determined by fiber length measurements of 10-, 15-, and 20-day-old bolls (Appendix Table 13). Since cotton fibers reach maximum length in about 18-20 days after flowers open, older bolls were not measured.

Leaf content of Ca and Mn increased with higher rates of CCC (Appendix Table 14). Rates of 18 g (a.i.) per ha and greater resulted in significantly higher amounts of these elements. Other minerals were not affected by treatment.

CCC rates ranging from 0 to 35 g (a.i.) per ha had no effects on yield (Table 15). The 280 g rate reduced cotton yields. Table 16 also shows a significant reduction in lint %, although this did not result in lint yield differences. A lint yield reduction trend from use of CCC seems to be possible. More of a beneficial yield response from CCC treatment would be expected in normal rainfall

Table 14. Effect of CCC on cotton plant height.¹

CCC rate g (a.i.)/ha	Time after CCC treatment, days		Final cm
	15 cm	30 cm	
0	86.3a	89.3a	91.1a
9	82.8ab	87.5a	86.5ab
9, 3 times, 10-day intervals	79.0ab	83.3ab	84.0ab
18	80.9ab	84.3ab	84.0ab
35	83.1a	86.8ab	83.8ab
280	75.8 b	80.1 b	81.0 b

¹ Treatments not followed by the same letter differ significantly at the 5% level according to Duncan's Multiple Range Test.

Table 15. Effect of CCC on cotton yield.¹

CCC rate g (a.i.)/ha	Seedcotton kg/ha
0	1883a
9	1875a
9, 3 times, 10-day intervals	1919a
18	1847a
35	1808a
280	1675 b

¹ Treatments not followed by the same letter differ significantly at the 5% level according to Duncan's Multiple Range Test.

Table 16. Effect of CCC on cotton quality.¹

CCC rate g (a.i.)/ha	Lint %	Bolls /kg no.	Fiber data				
			Strength MPa	Fineness mic	50% Length cm	2.5% Length cm	Uniformity ratio index
0	40.4a	180	89.3 b	4.6	1.35	2.87	46.9
9	38.9 b	179	88.0 b	4.6	1.30	2.85	45.5
9, 3 times, 10-day intervals	39.0ab	179	90.9ab	4.5	1.35	2.90	46.3
18	39.1ab	180	92.0ab	4.5	1.32	2.82	47.1
35	38.5 b	180	96.0a	4.5	1.30	2.82	45.8
280	36.4 c	176	93.2ab	4.4	1.35	2.95	45.8

¹ Treatments not followed by the same letter differ significantly at the 5% level according to Duncan's Multiple Range Test. There are no significant differences between treatments in columns that have no letters.

years. Evidence exists that CCC may be used at lower rates to obtain desirable effects of modifying vegetative growth without reducing yield.

Fiber strength was increased by CCC at 35 g (a.i.) per ha (Table 16). There were no differences between treatment effects on boll size, fiber fineness, length or uniformity.

Nitrogen Rate

Flowering rate and boll set for the initial 3 weeks of fruiting are shown in Table 17. The higher rates of flowering observed with the 168 kg N rate were not significant. In contrast, the % boll set was significantly higher in the 85 kg N plots. This resulted in essentially the same number of bolls set for both N rates.

The 168 kg N rate increased cotton plant height (Table 18). This was visually evident from early in the growing season until harvest. This indication of plant vigor was also expressed after defoliant application. High N plots were more difficult to defoliate (Appendix Table 23).

Nitrogen in the leaves was greater in the high N plants but other mineral elements were not affected (Appendix Table 19).

Even though the 168 kg N rate produced more vigorous plants under the dry conditions, there was no beneficial effect on yield (Table 19). Apparently, the increased % boll set measured during the initial 3 weeks of

Table 17. Effect of nitrogen rate on flowering and boll set of cotton.¹

Nitrogen rate kg/ha	Flowers ²	Boll set	Boll set
	no./m	no./m	%
84	42	20	49a
168	47	21	44 b

¹ Treatments not followed by the same letter differ significantly at the 5% level according to Duncan's Multiple Range Test. There are no significant differences between treatments in columns without letters.

² Flowers tagged daily, five days per week for three weeks immediately following CCC application.

Table 18. Effect of nitrogen rate on cotton plant height.¹

Nitrogen rate kg/ha	Time after CCC treatment, days		Final cm
	15 cm	30 cm	
84	79.0 b	82.9 b	81.6 b
168	83.6a	87.5a	88.5a

¹ Treatments not followed by the same letter differ significantly at the 5% level according to Duncan's Multiple Range Test.

flowering continued throughout the growing season. Dry weather resulted in a shorter than normal fruiting period and boll rot was not a factor (Appendix Table 22).

Nitrogen rate had little effect on cotton quality (Appendix Table 21). There were no differences between treatment effects on lint %, boll size, fiber strength, fineness, length or uniformity. Also, rate of fiber elongation was the same, regardless of N rate.

During normal rainfall years, interaction may exist between CCC and N rate. Dry weather may have been responsible for no interaction in these studies.

Table 19. Effect of nitrogen rate on cotton yield.¹

Nitrogen rate kg/ha	Seedcotton kg/ha
84	1851
168	1818

¹ Treatments are not significantly different at the 5% level according to Duncan's Multiple Range Test.

SUMMARY

Greenhouse Studies

CCC had no statistical effect on flowering rate during the initial 4 weeks of flowering in greenhouse studies. There appeared to be a trend toward CCC treatment increasing % flower set during this period. Flowering rate and boll set were reduced later in the growing season by CCC rates of 35 and 140 g (a.i.) per ha and greater, respectively. Consequently, total boll set per plant was reduced by chemical rates of 140 g and greater. CCC treated plants had shorter mainstem and fruiting branch internodes. Plant height was retarded from 9 to 33%. Potassium content of leaves was less and N higher in plants treated with the higher rates of CCC. CCC treated plants produced seed with a higher seed index and germination percentage.

Cotton leaf reducing sugars, number of days from open bloom to open boll, lint %, rate of boll development and weight of root systems were not influenced by CCC. However, visual observation of washed roots suggested that CCC may increase the number of fibrous roots.

Low light intensity caused a reduction in flowering rate, % flower set and number of bolls set per plant. These plants were taller with longer mainstem and fruiting branch internodes than plants subjected to normal light. Low light intensity also increased the interval from flowering to boll maturity.

Lint percentage, seed index and seed germination were not affected by different light intensities.

Field Studies

Below average rainfall probably reduced the degree of treatment effect in field studies. Height of drought stressed plants was retarded by only the highest CCC rate (280 g (a.i.) per ha). Calcium and Mn content of leaves was increased by CCC treatment but there was no effect on N, P, K, Mg, B, Cu, and Zn. CCC increased fiber strength but reduced lint %. There was a reduction in yield at the 280 g CCC rate but no yield differences occurred at lower rates.

In field studies, CCC had no effect on flowering rate, flower set or number of bolls set for the 3 weeks after chemical application. Rate of fiber elongation, boll size, fiber fineness, length and length uniformity were not affected either.

High N increased flowering rate but reduced % flower set. High N also increased plant height and N content of leaves and plants were slightly more difficult to defoliate. Cotton yields, fiber quality characteristics, boll size and rate of fiber elongation were not influenced by N treatment.

Dry weather may have been responsible for no interaction between CCC and N rates in these studies.

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APPENDIX

Appendix Table 1. Effect of CCC on flowering rate of cotton.¹

CCC rate g (a.i.)/ha	Time from first flower, weeks						
	1	2	3	4	5	6	7
	flowers/plant						
0	0.61	3.17	5.61	6.50a	6.56	5.39	1.50
9	0.61	3.33	5.06	6.22ab	5.83	4.89	1.22
18	0.50	3.17	5.78	5.89ab	6.28	5.28	1.89
35	0.78	3.17	5.11	5.50abc	6.17	3.39	1.22
70	0.61	3.39	5.17	5.61abc	5.22	3.72	0.94
140	0.67	3.56	5.33	5.17 bc	5.22	3.89	1.06
280	0.78	3.56	5.11	6.11ab	4.89	3.72	0.56
560	0.72	3.67	5.28	4.50 c	4.67	3.83	1.33

¹ Treatments not followed by the same letter differ significantly at the 5% level according to Duncan's Multiple Range Test. There are no significant differences between treatments in columns that have no letters.

Appendix Table 2. Effect of CCC on percent cotton flower set per plant.¹

CCC rate g (a.i.)/ha	Time from first flower, weeks						
	1	2	3	4	5	6	7
	flower set/plant, %						
0	38.9	87.9	38.6	33.7	40.3a	25.8ab	13.9
9	38.9	89.6	37.4	27.9	43.0a	36.1a	4.6
18	33.3	92.6	41.4	35.0	39.2a	21.9ab	5.6
35	50.0	91.0	42.8	30.0	26.8abc	36.9a	0.0
70	36.1	92.3	52.3	30.4	30.2ab	21.2ab	0.0
140	38.9	95.9	51.5	26.1	12.0 c	8.8 b	0.0
280	55.6	94.5	54.7	26.8	21.0 bc	7.4 b	11.1
560	33.3	100.0	51.3	19.3	11.5 c	7.4 b	0.0

¹ Treatments not followed by the same letter differ significantly at the 5% level according to Duncan's Multiple Range Test. There are no significant differences between treatments in columns that have no letters.

Appendix Table 3. Effect of CCC on cumulative percent cotton boll set per plant.¹

CCC rate g (a.i.)/ha	Time from first flower, weeks	
	1-4	1-7
	boll set/plant, %	
0	48.7	41.3
9	48.8	42.7
18	49.4	39.7
35	52.4	41.6
70	55.1	44.3
140	55.2	40.3
280	55.7	40.2
560	56.8	38.3

¹ Results of treatments are not significantly different.

Appendix Table 4. Effect of CCC on number of days from open cotton bloom to open boll.¹

CCC rate	Open bloom to open boll
g (a.i.)/ha	days
0	52.7
9	52.4
18	52.8
35	52.9
70	51.5
140	52.7
280	53.8
560	53.1

¹ Results of treatments are not significantly different.

Appendix Table 5. Effect of CCC on cotton lint percent.¹

CCC rate g (a.i.)/ha	Lint %
0	41.4
9	39.7
18	39.9
35	39.6
70	38.5
140	39.6
280	39.7
560	38.9

¹ Results of treatments are not significantly different.

Appendix Table 6. Effect of CCC on rate of cotton boll development and root system weight.¹

CCC rate g (a.i.)/ha	Age of boll, days			Root System ³ g/plant
	10 ² g/boll	20 g/boll	30 g/boll	
0	1.57	3.50	4.77	6.95
9	1.55	3.62	4.83	8.66
18	1.54	3.61	4.98	7.01
35	1.71	3.46	5.61	6.18
70	1.50	3.66	5.14	6.26
140	1.68	3.62	5.38	7.51
280	1.32	2.74	4.93	10.03
560	1.60	3.85	5.11	9.68

¹ Results of treatments are not significantly different.

² Dry weight per boll at specified age.

³ Dry weight per root system, 44 days after CCC treatment.

Appendix Table 7. Effect of CCC on mineral content and reducing sugars in cotton leaves.¹

CCC rate g (a.i.)/ha	Percent					PPM				
	Reducing sugars	P	K	Ca	Mg	N	Mn	B	Cu	Zn
0	0.8	0.2ab ²	4.7ab	2.7	0.6	3.8 bc	852	10	62	38
9	0.8	0.2 b	4.5abc	2.8	0.6	3.7 c	898	10	60	36
18	0.7	0.2ab	4.8a	3.0	0.6	3.8 bc	898	10	55	40
35	0.7	0.2a	4.7abc	3.0	0.6	3.9abc	898	9	70	42
70	0.7	0.2a	4.3 bc	2.9	0.5	4.0ab	875	11	55	40
140	0.7	0.2a	4.4abc	2.9	0.6	4.0ab	887	10	48	38
280	0.8	0.3a	4.2 c	3.0	0.7	3.9ab	898	9	66	52
560	0.8	0.2a	4.2 c	2.9	0.6	4.0a	898	10	50	49

¹ Leaf analysis made 44 days after CCC treatment. Results on a dry weight basis.

² Treatments not followed by the same letter differ significantly at the 5% level according to Duncan's Multiple Range Test. There are no significant differences between treatments in columns that have no letters.

Appendix Table 8. Effect of light intensity on flowering rate of cotton.¹

Light intensity	Time from first flower, weeks						
	1	2	3	4	5	6	7
	flowers/plant/week						
High	0.63	3.19 b	5.38	5.46	6.69a	5.29a	1.90a
Low	0.63	3.13 b	5.13	5.56	4.42 c	3.06 b	0.85 b
Normal	0.73	3.81a	5.42	6.04	5.71 b	4.44a	0.90 b

¹ Treatments not followed by the same letter differ significantly at the 5% level according to Duncan's Multiple Range Test. There are no significant differences between treatments in columns without letters.

Appendix Table 9. Effect of light intensity on percent cotton flower set per plant.¹

Light intensity	Time from first flower, weeks						
	1	2	3	4	5	6	7
	flower set/plant, %						
High	38.5	92.9	50.8a	29.0ab	20.4 b	26.6	4.9
Low	41.7	93.7	29.3 b	35.5a	40.2a	19.8	6.3
Normal	41.7	92.4	58.7a	21.3 b	23.3 b	15.7	2.1

¹ Treatments not followed by the same letter differ significantly at the 5% level according to Duncan's Multiple Range Test. There are no significant differences between treatments in columns without letters.

Appendix Table 10. Effect of light intensity on cotton boll set.¹

Light intensity	Time from first flower, weeks				
	1	2	3	4	5
	boll set/plant/week, no.				
High	0.58	2.98 b	2.69a	1.48 b	1.35
					1.52a
Low	0.60	2.92 b	1.44 b	1.94a	1.56
					0.79 b
Normal	0.71	3.56a	3.25a	1.31 b	1.42
					0.79 b
					0.15

¹ Treatments not followed by the same letter differ significantly at the 5% level according to Duncan's Multiple Range Test. There are no significant differences between treatments in columns without letters.

Appendix Table 11. Effect of light intensity on cotton seed index and germination.¹

Light intensity	Seed index g/100 seed	Germination %
High	12.0	86.6
Low	12.1	85.9
Normal	11.9	88.1

¹ Treatments are not significantly different at the 5% level according to Duncan's Multiple Range Test.

Appendix Table 12. Effect of CCC on flowering rate and boll set of cotton.¹

CCC rate	Flowers ²	Boll set	Boll set
g (a.i.)/ha	no./m	no./m	%
0	46	21	46
9	45	21	48
9, 3 times, 10-day intervals	48	21	45
18	42	20	48
35	45	21	47
280	44	20	45

¹ Treatments are not significantly different at the 5% level according to Duncan's Multiple Range Test.

² Flowers tagged daily, five days per week for three weeks immediately following CCC application.

Appendix Table 13. Effect of CCC on cotton fiber elongation.¹

CCC rate g (a.i.)/ha	Age of bolls, days		
	10	15	20
	fiber length, mm		
0	9.1	14.3	19.1
9	9.4	14.6	19.4
9, 3 times, 10-day intervals	9.4	12.4	19.5
18	9.3	13.6	19.9
35	9.8	14.1	19.6
280	9.4	14.0	19.5

¹ Treatments are not significantly different at the 5% level according to Duncan's Multiple Range Test.

Appendix Table 14. Effect of CCC on mineral content of cotton leaves.¹

CCC rate g (a.i.)/ha	Percent					PPM					
	N ²	P	K	Ca	Mg	Mn	B	Cu	Zn		
0	4.1	0.3	1.8	3.6	c	0.6	81	c	37	21	17
9	4.2	0.3	1.7	3.7	bc	0.6	101	bc	30	23	20
9, 3 times, 10-day intervals	4.1	0.3	1.7	3.9	bc	0.7	106ab	39	17	15	15
18	4.1	0.3	1.7	4.0ab	0.6	111ab	24	24	18	17	17
35	4.1	0.3	1.7	4.0ab	0.7	112ab	37	16	17	23	21
280	4.2	0.3	1.6	4.3a	0.7	127a	31	23	21	23	21

¹ Treatments not followed by the same letter differ significantly at the 5% level according to Duncan's Multiple Range Test. There are no significant differences between treatments in columns that have no letters.

² Leaf analysis made 30 days after first flower.

Appendix Table 15. Effect of CCC on cotton yield.¹

CCC rate g (a.i.)/ha	Cotton lint kg/ha
0	761a
9	728a
9, 3 times, 10-day intervals	748a
18	722a
35	696a
280	610 b

¹ Treatments not followed by the same letter differ significantly at the 5% level according to Duncan's Multiple Range Test.

Appendix Table 16. Effect of CCC on cotton boll rot.¹

CCC rate g (a.i.)/ha	Seedcotton rotted kg/ha
0	54
9	52
9, 3 times, 10-day intervals	57
18	52
35	37
280	44

¹ Treatments are not significantly different at the 5% level according to Duncan's Multiple Range Test.

Appendix Table 17. Effect of CCC on cotton defoliation.¹

CCC rate g (a.i.)/ha	Defoliation %
0	87.9
9	88.6
9, 3 times, 10-day intervals	89.0
18	88.3
35	89.8
280	87.9

¹ Treatments are not significantly different at the 5% level according to Duncan's Multiple Range Test.

Appendix Table 18. Effect of nitrogen rate on cotton fiber elongation.¹

Nitrogen rate kg/ha	Age of bolls		
	10	15	20
	fiber length, mm		
84	9.5	13.5	19.7
168	9.3	14.1	19.3

¹ Treatments are not significantly different at the 5% level according to Duncan's Multiple Range Test.

Appendix Table 19. Effect of nitrogen rate on mineral content of cotton leaves.¹

Nitrogen rate kg/ha	Percent					PPM			
	N2	P	K	Ca	Mg	Mn	B	Cu	Zn
84	4.0 b	0.3	1.7	3.9	0.7	100	34	20	18
168	4.2a	0.3	1.7	3.9	0.7	111	32	22	18

¹ Treatments not followed by the same letter differ significantly at the 5% level according to Duncan's Multiple Range Test. There are no significant differences between treatments in columns without letters.

² Leaf analysis made 30 days after first flower. Results on a dry weight basis.

Appendix Table 20. Effect of nitrogen rate on cotton yield.¹

Nitrogen rate kg/ha	Cotton lint kg/ha
84	712
168	710

¹ Treatments are not significantly different at the 5% level according to Duncan's Multiple Range Test.

Appendix Table 21. Effect of nitrogen rate on cotton quality.¹

Nitrogen rate kg/ha	Lint %	Bolls no./kg	Strength MPSI	Fineness mic	Fiber data		
					50% Length cm	2.5% Length cm	Uniformity ratio index
84	38.4	179	92.0	4.5	1.32	2.90	46.0
168	39.0	181	91.1	4.6	1.32	2.85	46.4

¹ Treatments are not significantly different at the 5% level according to Duncan's Multiple Range Test.

Appendix Table 22. Effect of nitrogen rate on cotton boll rot.¹

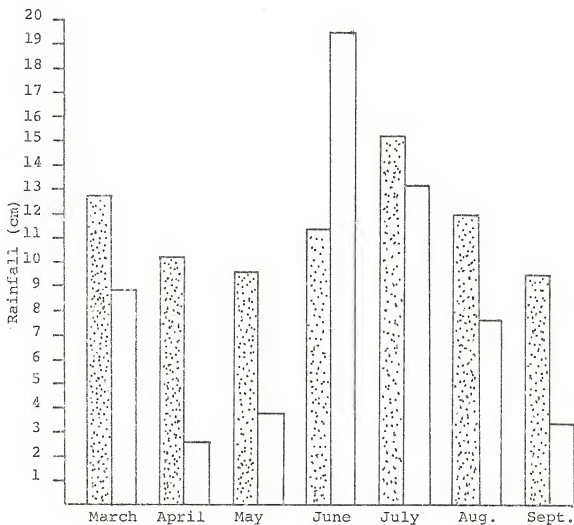
Nitrogen rate	Seedcotton rotted
kg/ha	kg/ha
84	45
168	53

¹ Treatments are not significantly different at the 5% level according to Duncan's Multiple Range Test.

Appendix Table 23. Effect of nitrogen rate on cotton defoliation.¹

Nitrogen rate	Defoliation
kg/ha	%
84	89.4a
168	87.8 b

¹ Treatments not followed by the same letter differ significantly at the 5% level according to Duncan's Multiple Range Test.



Thirty year average rainfall from 1931 through 1960.



1972 rainfall.

Appendix Figure 1. Total rainfall per month for 1972, showing departure from normal.

BIOGRAPHICAL SKETCH

Charles R. Roland was born September 12, 1938, in Bleckley County, Georgia. He is a graduate of Cochran High School, Middle Georgia College and received BSA and MSA degrees from the University of Georgia with a major in Agronomy. In 1962, he was employed with the University of Georgia Cooperative Extension Service as Assistant County Agent in Twiggs County. He later served as County Agent - Chairman in Twiggs and Worth counties. He became a member of the Extension Agronomy Department in 1967 as a Tobacco Agronomist and later as Extension Agronomist - Cotton. In June, 1970, he enrolled in the Graduate School of the University of Florida where he is now a candidate for the degree of Doctor of Philosophy.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

E. B. Whitty

E. B. Whitty, Chairman
Associate Professor of Agronomy

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

E. G. Rodgers

E. G. Rodgers
Professor of Agronomy

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Charles F. Douglas

C. F. Douglas
Professor of Agronomy
University of Georgia

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

V. N. Schroder

V. N. Schroder
Associate Professor of Agronomy

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

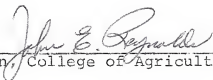


W. G. Blue

Professor (Biochemist) of Soils

This dissertation was submitted to the Dean of the College of Agriculture and to the Graduate Council, and was accepted as partial fulfillment of the requirements for the degree of Doctor of Philosophy.

June, 1973


asst. Dean, College of Agriculture

Dean, Graduate School

372⁶